

MEMORANDUM

RM-4220-PR

APRIL 1965

STUDIES IN DATA SYSTEM DEVELOPMENT:
THE OCAMA WEAPON SYSTEM PROJECT

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This research is sponsored by the United States Air Force under Project RAND—Contract No. AF 49(638)1-700 monitored by the Directorate of Development Plans, Deputy Chief of Staff, Research and Development, Hq USAF. Views or conclusions contained in this Memorandum should not be interpreted as representing the official opinion or policy of the United States Air Force.

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PREFACE

Inventory management was early recognized in both the Air Force and industry as a function particularly susceptible to improvement by automation. The Air Force, with inventories numbered in millions of parts and valued at billions of dollars, began introducing computers into various aspects of inventory management in the mid-fifties. The experience of the past decade offers valuable insights into the nature of inventory management itself and into the development of automatic data processing systems to support it.

This Memorandum examines a pioneering Air Force effort to apply the electronic computer to inventory management -- the stock control and distribution system developed and operated by the Oklahoma City Air Materiel Area (OCAMA). Looking across the nine-year history of the system, the Memorandum discusses changes in the system concepts, operations, and data-processing equipment configuration. From the OCAMA experiences, conclusions are drawn for guidance in developing other large scale data systems.

This is the third in a series of studies examining automated data system development in the Air Force. The other studies are: R. J. Mason, K. H. Meyer, and R. L. Van Horn, Studies in Data System Development: The Vandenberg Air Force Base Project, RM-3836-PR, For Official Use Only, March 1964; and S. L. Pollack, Studies in Data System Development: The Air Reserve Records Center, RM-4188-PR, July 1964. The Automatic Resupply Logistics System (ARLS) will be reported on subsequently, and a final Memorandum will draw from the experience and lessons of all four systems to suggest appropriate principles for data system development.

This Memorandum should be of particular interest to members of the Directorate of Data Automation and the Office of the Assistant for Logistics Planning, Headquarters USAF; the Directorate of Operations, Headquarters, Air Force Logistics Command; and others concerned with data system development.

SUMMARY

Based on a concept suggested by The RAND Corporation in 1955, the stock control and distribution system developed and operated by the Oklahoma City Air Materiel Area (OCAMA) stands as one of the most successful examples of Air Force experience in data system development. A signal characteristic of this system is its history of "phased development" -- the evolution of the system in discrete stages.

The original RAND concept envisioned all Air Force materiel control functions, including stock distribution, maintenance scheduling, requirements calculation, and procurement computations, as being performed at a few data-processing centers. These centers would maintain worldwide balances for assigned items and would initiate automatically the resupply of parts to all locations based upon data supplied automatically from parts users and suppliers. A key concept was the management of stocks at a different location from that of their physical storage. The centrally-located computer was the management tool.

OCAMA modified and refined the concept and applied it to several weapons systems, principally the B-52 and KC-135. The major changes in concept narrowed the system functions to stock control and distribution and eliminated the maintenance of base balances, leaving these entirely with base level systems. Since its beginning in 1955, the system has developed through four basic and four auxiliary phases, and has employed six different configurations of data-processing equipment.

As the system has moved from phase to phase, improvements have centered on a) making possible faster response to high priority requests, b) facilitating reports which are more useful to support managers, and c) increasing equipment efficiencies, with attendant cost savings. A major management innovation has been the development and programming of intricate procedures for handling spare parts that are interchangeable according to various rules. As experience has accumulated, the trend has been to simplify several of the

management concepts originally built into the system. For example, substitution relationships have been reduced and elaborate calculations of stock management levels have been substantially simplified. Throughout its life, the OCAMA system has met its operational objectives, an achievement largely attributable to the following factors, which also provide guidance for other data system development efforts.

First, the system concept had a specific focus -- the stock control and distribution phase of inventory management. Although the original RAND concept included other functions, it was early decided that stock control and distribution were fundamental and provided a necessary foundation for other materiel functions. The lesson appears to be that in creating a large scale system eventually intended to embrace many functional areas, the fundamental area should be developed first -- rather than all functions in parallel. This approach does not preclude eventual development of the system as an integrated whole, nor does it constrain the spectrum of intended accomplishments. The concept may be comprehensive, but implementation within the framework of this concept should be planned in discrete, sequential steps.

Second, each phase was successfully operated before the succeeding phase was undertaken. If OCAMA had not first had an operating punch card inventory control system (and the follow-on interim IBM 650 tape system), it is almost certain that the pressures to get the Phase I system "on the air" would have been considerable. With these systems, which performed adequately if not elegantly, the new stock control and distribution system was not forced into operation until it was fully ready. This philosophy of implementation continued through all of the system's phases. Delays in implementing any phase would not have been disastrous, since a working system was in existence. All this emphasizes the desirability of providing for phased development in which each phase in itself provides a system that satisfies basic operational requirements.

Third, each phase was used as an opportunity for collecting information about the system and the weapon manager's data needs and decision processes. Much of such information could (and, in most

systems, can) be learned only by involvement with an operating system. This was especially true in the OCAMA case, where the system concept, the data-processing equipment used, and the weapons system involved were all new. Each phase thus formed an improved conceptual and operational foundation for the succeeding phase.

To summarize: OCAMA's successful experience suggests the principle that new, complex data systems should be developed from concepts having specific focus and providing implementation in discrete phases, each of which constitutes in itself an operating system.

ACKNOWLEDGMENTS

The authors wish to acknowledge the assistance of several Air Force and RAND personnel in the preparation of this Memorandum. Charles B. Scott, Chief, Weapons Section, Commodity and Weapons Systems Branch, Data Services Division in the Comptroller's Office of OCAMA, who has been associated with the project from its beginning, was very helpful in supplying information and commenting on the Memorandum in draft. In the latter task, he was joined by his colleagues Jack L. Davis and Raymond L. Reynolds. Colonel Howard B. Seim, Jr., Comptroller of OCAMA, and A. H. Rosenthal and J. D. Tupac of RAND also read the draft Memorandum and provided useful comments. The interpretations and conclusions remain the authors' responsibility.

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I. INTRODUCTION

During the past decade, the Air Force has developed many large-scale electronic data-processing systems. Among these, the stock control and distribution system for the B-52/KC-135 weapon systems stands as one of the most successful. Based upon a concept suggested by The RAND Corporation in 1955, this system has been developed and is today operated by the Oklahoma City Air Materiel Area (OCAMA) of the Air Force Logistics Command.

This Memorandum describes the development and operation of this system and explores the conditions that appear to explain its success.*

A signal characteristic of OCAMA's system is its history of "phased development" -- the evolution of the system in discrete stages. Since this characteristic appears to have contributed substantially to the success OCAMA has enjoyed, the Memorandum is organized into sections describing each phase. A concluding section looks across the decade of the system's history and draws conclusions relevant to the general problem of large data system development and implementation.

*The B-52/KC-135 Weapon System Stock Control and Distribution application is one of several data-processing applications performed on OCAMA computers. This Memorandum concerns only this application, and frequently refers to it as the "OCAMA system."

II. SYSTEM CONCEPTION

BACKGROUND

In 1954, RAND made a study of all the functions related to materiel which take place at base and depot levels in the Air Force, including materiel control, distribution, maintenance scheduling, requirements computations, transportation scheduling, and in-transit control. The study examined in detail ways in which Air Force supply procedures, particularly those dealing with stock control and distribution and requirements calculations, might be revised in order to exploit the potentialities of both the then available and forthcoming electronic data processors. Published in RAND RM-1417, January 1955,* the study concluded that advances in electronic data processing would permit the Air Force to manage its materiel more effectively than ever before by making it possible to bring together concurrently all information relevant to distribution, control, and procurement decisions.

Briefly, the study envisioned a concept wherein all Air Force materiel control, including distribution of stock, scheduling and maintenance, requirements calculations, and procurement computations, would occur at a few data-processing centers (one in the Continental United States and several overseas). Each of these centers would have prime responsibility for a certain group of the 1,500,000 items of Air Force stock and would maintain worldwide balances of the items for which it had such responsibility. Any resupply of an item to any location (whether it was a base, Air Materiel Area, or storage site) would be automatically initiated by the data-processing center responsible for that item, the decision being based on programmed decision rules applied by the electronic data processor; the management of stocks would thus be performed at a different location from their physical storage site.

* R. B. McNeill, E. B. Berman, A. J. Clark, H. W. Nelson, A Proposal For a New Air Force Supply Procedure, The RAND Corporation, RM-1417, January 1955.

The concept presented was the first of its type and attracted much interest in the Air Force -- especially in the Headquarters of the Air Force Logistics Command (then called the Air Materiel Command) and the Oklahoma City Air Materiel Area (OCAMA).

OCAMA was interested in the concept because they had what appeared to be an excellent application for its use -- the management of spare airframe parts for the B-47 aircraft. Also, OCAMA was scheduled to receive (in August 1955) an IBM 702 computer. This computer was to be used for applications other than B-47 spare parts management, but would have unused time which could be made available for service testing the new RAND concept of materiel control.

RAND was equally interested in carrying out a service test of the concept, so an agreement was made among the Air Force Logistics Command (AFLC), OCAMA, and RAND for the use of OCAMA's new computer in a test of the RAND materiel control concept.^{*} The materiel to be controlled was all B-47 airframe-peculiar spare parts (property class LAFE).

RAND and OCAMA worked together on the development and implementation of the concept from early 1955 until about June 1957, at which time OCAMA took over on its own, with RAND offering occasional help and advice. The major OCAMA organization involved in developing and operating this system has been the Data Services Division, Comptroller.

From the original RAND concept, the OCAMA system has moved through several phases and has employed different data-processing equipment configurations. Table 1 summarizes these and other relevant characteristics of the OCAMA experience. The table indicates that there have been four different basic system phases plus four auxiliary projects. These eight systems have been used in conjunction with six different configurations of data-processing equipment.

The following sections of this Memorandum describe the major system phases and explain why they were implemented and what they accomplished.

* Headquarters, Air Materiel Command (AMC) Letter, MCC, "RAND Corporation Experiments in Logistical Data Processing Using AMC Electronic Computer," April 29, 1955.

OCAMA WEAPON SYSTEM STOCK CON

EQUIPMENT	BASIC	AUXILIARY	PHASES	MAN-YEARS AND CALENDAR DATES OF DEVELOPMENT		DATES USED	MAIN CHARACTERISTICS
				OCAMA	RAND		
IBM 702/TAPE	A		ORIGINAL RAND CONCEPT (RM 1417, 1/24/55)	1.25 8/55-1/56	2.0 11/55-1/56	NEVER IMPLEMENTED	1. SINGLE MASTER RECORD 2. NO FAMILY AND SUB-FAMILY 3. LIMITED AMOUNT OF SUBFORMATION RECORDED 4. FOR ITEM MANAGEMENT (TAPE SPARES)
	B		PROJECT AF-GEN	20 8/55-5/56	1.2 9/55-5/56	MAY, 1956 FEB, 1957	USE OF REMOTE EDP 1 TO ACCOUNT FOR AND WAR RESERVE TABLES
IBM 650/TAPE		C	MARK SENSE OFFSET SYSTEM CONVERTED TO TAPE IMARK SENSE SYSTEM USED FROM JULY 56 TO JULY 57	0.5 3/57-6/57	-0-	JULY, 1957 DEC, 1957	1. PUNCH CARD SYSTEM C TO TAPE 2. MASTER ITEM RECORD (TAINED ITEM BALANCES) 3. MANAGEMENT OF ITEMS MANUALLY
IBM 709 11/TAPE	D		PHASE I SYSTEM (REVISED RAND CONCEPT)	50 1956-1958	10 2/56-10/57	DEC, 1957 MAR, 1960	1. EMPLOYED 2 MASTER RECORDS a. SUBSTITUTION AND ALL b. MAIN BALANCE MASTER 2. MANAGED INTERCHANGEABLE ITEM 3. AUTOMATICALLY SELECTED 5 4. USED LEVELS AND PRIORITIES AND DISTRIBUTE STOCKS
				20 ⁽¹⁾ 1958	-0-		
IBM 705 11/DISK a. SINGLE DENSITY DISKS 1201 APRIL, 1960 b. DOUBLE DENSITY DISKS 1301 NOV 15, 1961	E		PHASE II SYSTEM	17 2/59-3/60	75 1956	APRIL 1960 TO JULY, 1962	1. EMPLOYED 1 MASTER RECORD STORED ON MAGNETIC DISK 2. } 3. } SAME AS PHASE I SYSTEM 4. }
	E1		PROJECT MILSTRIP	5 1/62-6/62	-0-	JULY, 1962 TO NOV, 1963	REPROGRAMMING OF THE NEW DEPARTMENT OF DEFENSE REQUISITION AND ISSUE
IBM 7080-DISK DEC, 1963		E2	PHASE II SYSTEM	6.2	-0-	DEC, 1963 TO APRIL, 1968	SAME AS PHASE II SYSTEM
IBM 7080/TAPE/DISKS (6) MAY, 1966	F		PHASE III SYSTEM	15 3/63-12/63	-0-	MAY, 1966 TO PRESENT	1. SINGLE MASTER RECORD STOCK NUMBER SEQUENCING 2. ABBREVIATED MASTER RECORD FOR PRIORITY PROCESSING 3. } 4. } SAME AS PHASE I NOS 5. }

ND DISTRIBUTION SYSTEM

SYSTEM

	MAIN ADVANTAGES OF SYSTEM	MAIN DISADVANTAGES OF SYSTEM	MAIN REASONS FOR DISCONTINUING SYSTEM	IMPACT ON OTHER AF SYSTEMS
6 IS	FIRST ATTEMPT AT DESIGNING A CENTRALIZED EDP SYSTEM FOR MANAGING AF SPARE PARTS	INABILITY TO MANAGE INTERCHANGEABLE ITEMS	BETTER MANAGEMENT OF INTERCHANGEABLE ITEMS	BASIC SYSTEM FROM WHICH PHASE I WAS DEVELOPED
	PROVED FEASIBILITY OF CENTRALIZED MANAGEMENT OF STOCKS BY USE OF EDP EQUIPMENT AND ELECTRICAL COMMUNICATION EQUIPMENT		ABANDONMENT OF CONCEPT OF INVIOLENT WAR RESERVE STOCKS	INCREASED FAITH ON PART OF AF PERSONNEL IN FEASIBILITY OF PHASE I SYSTEM
1 N	1. FIRST MAGNETIC TAPE ACCOUNTING SYSTEM 2. MORE ACCURATE THAN MANUAL OR PUNCH CARD SYSTEM 3. DATA WAS "CLEANED UP" WHEN TRANSFERRED TO TAPE 4. STARTED STORING ISSUE HISTORY ON TAPE 5. AIDED CONVERSION TO PHASE I	AN ACCOUNTING SYSTEM ONLY	WAS RECOGNIZED AT THE OUTSET AS AN INTERIM SYSTEM BETWEEN PUNCH CARD SYSTEM AND FUTURE EDP MANAGEMENT SYSTEM	
1 STER ONE ITEMS TROL	AUTOMATIC CONTROL AND DISTRIBUTION OF STOCKS	INABILITY TO HANDLE HIGH PRIORITY REQUESTS ON IN-LINE RANDOM ACCESS BASIS	TO GAIN RANDOM ACCESS CAPABILITY	1. USED AS A MODEL FOR AF ITEM MANAGEMENT TAPE SYSTEM 2. USED AS A MODEL IN EARLY PHASES OF ARLS SYSTEM AT SBAMA
1 3. 4 VRT	ABILITY TO HANDLE HIGH PRIORITY REQUESTS ON 20 SECOND BASIS BY USE OF RANDOM ACCESS EQUIPMENT	RECORDS STORED RANDOMLY ON DISK - REQUIRES DISK DUMP ONTO TAPE AND LENGTHY TAPE SORTING TO PRODUCE REPORTS IN STOCK NUMBER SEQUENCE	1. INCREASE CAPACITY OF DISKS RESULTING IN a. 9 LESS DISK UNITS FOR PRESENT WORKLOAD, AND b. ABILITY TO HANDLE 20 WEAPONS INSTEAD OF THE PRESENT 4 2. AVOID DISK FILE DUMPS AND EXCESSIVE TAPE SORTING 3. ANNUAL EQUIPMENT SAVINGS \$605,076	USED AS A MODEL FOR AF ITEM MANAGEMENT RANDOM ACCESS SYSTEM (PRIORITY DISTRIBUTION SYSTEM)
2. 3. 4	DECREASED PROCESSING TIME			
1 DISK	1. INCREASED STORAGE CAPABILITY ON DISK FOR RANDOM ACCESS PRIORITY PROCESSING 2. ELIMINATE DISK DUMPS AND REDUCE TAPE SORTS 3. DISKS AVAILABLE MORE HOURS FOR PRIORITY PROCESSING 4. LESS PROCESSING TIME			

THE ORIGINAL RAND CONCEPT

The RAND concept for management of aircraft spare parts published in early 1955 embodied the following main features:

1) There would be a data-processing center (which RAND called a Supply Services Center) maintaining on hand balances for all items in all base and AMA supply accounts, wherever located; these balances would be adjusted each day in accordance with transaction information received by the Center via electrical communication links.

2) Upon need of replenishment, stock maintained at each base would be automatically resupplied by the initiation of a materiel release order at the Center to cause movement of needed stock to the base. The balances on hand for the sources of supply would be adjusted in accordance with the materiel release orders issued.

3) Since the Center would maintain current balances for the bases, formal balances would not be maintained at each base.

4) If the base needed a part not on hand, it would requisition the part from the Center. Very little base requisitioning was expected, since most parts would be supplied and replenished automatically.

5) If a request from a base could not be honored -- either because of an insufficient priority in relation to the quantity on hand, or because there was no quantity on hand -- the Center's computer would automatically select a substitute part, causing it to be shipped to the base.

6) Control of all items "due in" to the system from outside contractors would be maintained by the Center.

7) Control of all shipments "in transit" between any two Air Force installations would be maintained by the Center.

8) The Center would control all "backorders" (requests not yet filled but for which an attempt would be made in succeeding cycles). Each day a request remained unfilled would result in an upgrading of its priority, if appropriate, thereby increasing its chance of being filled in the next processing cycle.

9) The Center would maintain data on accumulated issues so that reorder and stock control levels could be calculated for the computation of requirements and budgets on a world-wide basis.

These were the main aspects of the inventory control system RAND proposed in 1955. With four exceptions, these basic ideas are close to those used in the current version of the system.

The first exception (No. 5) concerned the selection of a substitute part when a requested part was unavailable. The substitution procedure has probably been the most important factor in determining the character of the system as it has passed through each successive phase. For this reason, the following paragraph describes the original concept of substitution; the subsequent sections about each phase deal with how the problem has been handled in that phase of the system.

The original substitution concept proposed a "master balance tape," which would contain one master record for each spare part (line item). Each record would contain information concerning the part (e.g., balance on hand, and reorder level) and each location where it was stocked. Incoming transactions were first to be matched against an "allocations tape," and a determination made as to whether the total amount of priority requests on the incoming transactions tape could be satisfied from available balances. If not all requests for a line item could be satisfied, the computer would allocate the quantity available in accordance with the priorities of the requests. If a request could not be satisfied by this allocation procedure, a substitute part was identified from information in the part record. The "substitute" transactions would be read out, sorted into stock number sequence, and merged into another transactions tape, which would then be posted against the master balance file. Substitute parts would then be issued to fill requisition demands.

The other exceptions (Nos. 1, 2, and 3) relate to the handling of base balances and are discussed in Section III.

Implementation of the original RAND concept barely got under way in mid-1955 when a large portion of the personnel (both OCAMA and RAND) involved was diverted to the systems and programming work

of the AF-GEN project, in which they were involved from about August 1955 until May 1956.

While the AF-GEN project was not intended to be a part of the basic inventory control system, it appeared at the time that something would be learned from the project which could be of value in developing the basic system. The next section therefore describes the AF-GEN project and why it was important to the stock control and distribution system.

THE AF-GEN PROJECT

The AF-GEN project concerned applying remote input-output electronic data-processing techniques to the accounting and control of war reserve spare parts stored at Slack Air Force Station, Shreveport, Louisiana. The project is of interest in the development of the OCAMA system because the Air Force concluded that it demonstrated, to some extent, the feasibility of centralized management of stocks from a remote location -- one of the ideas advanced in the RAND concept.

The AF-GEN program, in brief, consisted of a data-processing center located at OCAMA which maintained the accountable records and source data for war reserve stocks maintained at Slack Air Force Station. The OCAMA center had the following responsibilities for the stocks at Slack, which were stored in the form of inviolate, assembled, prepositioned packages of spare parts to support specific operational missions:

1. Controlling the assembly of the materiel at Slack;
2. Accounting for and controlling the materiel during its storage;
3. Providing accurate and timely management reports;
4. Controlling "dated" type items or items requiring periodic inspection and/or maintenance while in storage;
5. Providing responsive compliance with directed changes in "package" contents;

6. Providing flexibility to allow dispersal of packaged materiel to any extent necessary to insure invulnerability; and
7. Minimizing administrative workload at the storage location (the storage site at Slack maintained no balance records of the items stored there).

The AF-GEN project appears to have been the first Air Force attempt at separating the management and record-keeping for stocks from their physical storage. The system became operational in May 1956 and was used until about February 1957. The reason for its discontinuance was a change in the Air Force's concept of inviolable war reserve stocks. Rather than actually shipping the materiel to a separate site and attempting to keep it in a continued state of readiness, the Air Force decided to keep the war reserve stocks in the same bins as active stocks. This would ensure a continual rotation of the stocks since the oldest item would be issued first. The war reserve stock would thus be continually "fresh." The management of the individual stock items would also be simplified considerably, especially "dated" items and those requiring periodic inspection and maintenance. To insure that the quantity of items required for war reserve was always on hand, a war reserve level, below which no issues can be made, was employed. The actual items stocked to satisfy this level were continually rotated, the oldest being issued first.

During AF-GEN's brief operational life, some problems were experienced in data transmission between the storage site (Slack) and the data-processing center (OCAMA). Transmission was accomplished by a transceiver device that accepted punch cards, converted the data into signals that are transmitted electrically, and reconverted them into punch cards at the receiving station. There was also some difficulty in getting the distant warehouse personnel to follow instructions from the center. However, it is generally agreed that the project did prove the feasibility of managing stocks from a data-processing center, using electrical communications between the center and a remote warehouse location. This experience tended to

increase the confidence of the OCAMA personnel in continuing the work on the basic system.

While the majority of the OCAMA personnel were diverted to AF-GEN, * a skeleton force continued with the design and development of the basic system. Because of the resultant slowdown in the pace of work, the original RAND proposal was more carefully studied and the basic concept revised. The revised RAND concept, which became the basis for subsequent implementation, is known as the OCAMA Weapon System Stock Control and Distribution System -- Phase I.

* Systems development and computer programming for the AF-CEN project involved about 20 man-years of Air Force personnel time and 1.2 man-years of RAND effort.

III. SYSTEM DEVELOPMENT AND OPERATION

PHASE I SYSTEM (Revised RAND Concept)

The main deficiency in the original RAND concept was its insufficient recognition of the Air Force's policy of managing spare parts which are interchangeable with each other as single items. Under this policy, levels are set for an entire group of interchangeables as a unit so that no decision is made regarding the issuance of any one part without knowing the complete picture concerning all parts with which it is interchangeable. This deficiency in the original RAND concept became apparent during late 1955, so in March 1956 a new approach was undertaken to remedy it.

The new approach led to the adoption of four basic terms to define the major categories of parts (for purposes of interchangeability):

Bachelor Part: One which can not be used as a substitute for another part and for which no other part can be a substitute. If all parts were of this type, the original RAND concept would have sufficed. Bachelor items did not influence the development of the revised concept.

Interchangeable Parts: Two or more parts which can be substituted for each other in any and all situations. Assuming parts A, B, C, and D are interchangeable, a request for part B, for example, can be filled by a shipment of part A, C, or D, as well as by a shipment of part B. A group of such parts which are interchangeable is designated a "subfamily." Thus parts A, B, C, and D belong to the same subfamily.

Substitute Part: A part which can be used in place of another part, without reverse substitutability. For example, part F may be used in place of part E, but part E cannot be used in place of part F (if it could, the two parts would be interchangeables rather than substitutes). There is an added degree of substitution in this notion. Taking the same example, it could be that part F could be substituted for part E in all situations or in certain applications only. For instance, it is possible that part F could be substituted

for part E only if the part were to be used on aircraft of a certain type and model (and even a certain series). In the first instance, F would be a substitute for E. In the second, F is designated a "limited substitute."

Family: A group of "subfamilies" (the latter being a group of interchangeable parts). The reason for grouping certain subfamilies into a family is that there is a substitute relationship which links at least one part in each subfamily with at least one part in another subfamily. Take, for example, the following family having four subfamilies;

<u>Subfamily</u> <u>Number</u>	<u>Parts</u>
1	A B D G
2	K M
3	L P R
4	C

In the example, any two parts on the same horizontal line are interchangeable with each other in all situations. The reason subfamilies 1, 2, 3, and 4 are grouped into the same family is that there are substitute relationships connecting them. It might be that part M is a substitute for D (but D is not a substitute for M -- otherwise the two parts would be in the same subfamily), or it might be that M is a limited substitute for D (based on aircraft type, model, and serial number).

This concept of subfamilies and families made it possible to develop a revised system which would handle the Air Force's requirement for managing parts that were interchangeable with each other as one item. This meant that before decisions were made as to the shipment or resupply of an item, the asset position (balances) of the entire subfamily of which it was a member would be considered -- rather than the asset position of the item alone. The family-subfamily concept had the most significant effect on the revised system, and determined how many machine runs would be needed per processing cycle, what the cycles would consist of, what the master records would

contain, and how long the master records would be. The following paragraphs describe the system for carrying out this concept.

In order to handle transactions pertaining to any non-bachelor part, the most convenient system would be one wherein all the main balance records for the part's entire family would be brought into the main memory of the computer at the same time. This would satisfy two requirements: first, all parts belonging to the same subfamily could be managed as one, and second, the availability of all possible substitute and interchangeable parts for any part in the family could be readily determined.

As a practical matter, however, it did not appear possible to store all the master records for an entire family in the main memory of the computer at one time. The computer for which the revised system was being designed was the IBM 705 II, with 40 thousand characters of main memory, and this was not sufficient to store an entire family of master records in addition to the storage needed for the program and processing. Unfortunately, the maximum or even the average number of parts in a family was not accurately known at the time, but the educated guesses of most supply experts led to the conclusion that the maximum number of such parts would easily exceed 100. It was later learned that this was a highly inflated estimate.

For purposes of comparison with the original inventory control system, the salient features of the revised system will be described, showing the effect of using the family-subfamily concept.

Figure 1 shows a simplified diagram of the system. The major pertinent processing actions will be discussed for each computer run, one of which each block represents.

The "Edit" run handles all transactions and is intended primarily to detect errors in the transactions and adjust input record format. If an error is detected, the computer may either correct it and continue processing, or may reject the erroneous transaction and continue processing the succeeding transactions. The main types of error detection routines handled in this run are:

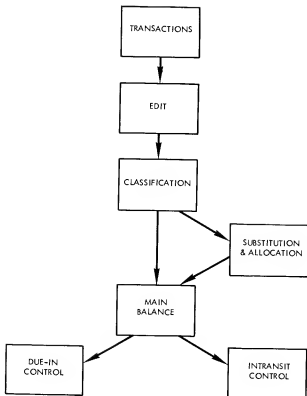


Fig. 1 -- The OCAMA Phase I System

1. Transaction checks
 - a. Completeness of required information on each type of transaction
 - b. Validity of each transaction
2. Batch controls -- to insure inclusion of all transactions

The edit run also rearranges the information on the input transactions into a form more convenient for processing in subsequent computer runs.

After the edit run, the transactions are ready for processing. Transaction processing is organized into three runs, labeled "Classification," "Substitution and Allocation," and "Main Balance."

In the classification run, all transactions are matched against a master index file containing one record for each part in the system. Items of information peculiar to each individual part are checked for accuracy. One verification of this type is the unit of issue; each transaction is checked to determine that the quantity requested is expressed in the same units by which the part is designated in the master balance record. The accuracy of stock number itself is also checked and corrected. For example, if the stock number in the transaction has been changed, the corrected number is assigned automatically.

Finally, the classification run determines whether or not the part number is a member of a family of parts or if it is a bachelor item. If the part belongs to a family, the family number is added to the transaction. If the part is a bachelor item, it needs no additional information. The transactions which come out of the classification run are put onto two separate magnetic tapes: one tape consisting of all transactions for family items, the other consisting of bachelor item transactions. Eventually, both sets of transactions will be processed in the "Main Balance" run (as shown in Fig. 1), but prior to this run, the family transactions are processed in the "Substitution and Allocation" (S&A) run.

The S&A run consists of processing all transactions for family items against the S&A master file. The S&A master file consists of a record for each family of parts, arranged by family number. The record contains inventory balances and levels by individual part and

by subfamily. These balances are for the world-wide system (all stock storage locations), not for each individual location. The record shows all interchangeability and substitution relationships in the family, including limited substitutions appropriate only for certain types, models, or series of aircraft. In the S&A run, all non-requisition transactions (receipts, stock list changes, etc.) are first posted to the master record; then requisitions are handled.

Having the system balances and levels by part and by subfamily enables the management of each group of interchangeable as one item. Having a complete family record in the computer at one time enables the selection of an interchangeable part or a substitute part if the requested part cannot be shipped. It is basically in the S&A run that distribution actions are directed. If a requested part can be shipped (on a basis of priority of the request and the subfamily balance on hand), the transaction passes to the Main Balance run. If the requested part is unavailable, an attempt is made to select an interchangeable or substitute part in satisfaction of the request. For some parts there are required substitutes, this being a means for purging the system of older items before they become obsolete.

After the S&A run, the pre-processed family transactions are merged with the bachelor transactions by stock number, and all transactions are processed against the master balance file in the "Main Balance" run. The master file for this run consists of a record containing management levels and balances by location for the entire system, for each stock number. All transactions are posted to this record and nearly all requests for family items can be filled because the S&A run pre-screened them on a family basis.

The other two major runs shown in Fig. 1 are for the purpose of controlling shipments from outside the system to locations within the system (Due-in) and for controlling shipments between locations within the system (Intransit).

The Phase I daily processing cycle for "routine" transactions took approximately 8 hours for all the computer runs. High priority requisitions were handled on a manual basis by the weapon system manager, who used a weekly balance register for all parts and daily transaction registers.

During the two-year period of developing and implementing the Phase I system, three major changes occurred. First, the computer involved was changed from an IBM 702 to an IBM 705 II, because the latter provided substantially greater capability. Second, the inventory class to be controlled was changed from class LAFE spare parts for the B-47 to LAFG for the B-52 and KC-135 weapon systems.* This was done because the B-52 and KC-135 were being phased into the Air Force, and it appeared that the B-47 would soon be phasing out. Also, the B-52 and KC-135 were to be managed under the new weapon system concept (as opposed to the item management concept for the B-47). Since it was expected that the weapon system concept would eventually be used Air Force-wide, it was decided that the new and advanced stock control and distribution system should be developed to support it. The change in computers meant that increased capacity was available for running the programs, but it had relatively minor impact on the inventory system. Changing to the weapon system concept and the B-52/KC-135 aircraft similarly had little effect, since the revised inventory data system was equally workable for either concept. The impact of RAND's weapon system management concept on the Air Forces' item management system is discussed further in Section IV.

The third, and most basic, change from the original RAND concept concerned the maintenance of stock balances at Air Force bases. Originally, individual bases were expected to maintain no inventory balance records of their own: they were only to have warehouse locator and bin cards sent to them by the data-processing center with each shipment of inventory. The center would maintain all base inventory records and initiate any automatic resupply based on these records. However, the Strategic Air Command (SAC), which operated the bases for the B-47, B-52 and KC-135, was understandably

*Headquarters, AMC Letter Number 25-127, "Data Development Project -- Weapon-System Stock Control and Distribution," assigned OCAMA as pilot depot to develop and program weapon-system distribution functions for the B-52/KC-135 in accordance with policies and procedures prescribed in Vol. XX, AFM 67-1.

reluctant to give up its record-keeping activities until the new system had been proven. The system concept was therefore revised so that base inventory records were maintained under the jurisdiction of SAC; only weapon system storage site balances were maintained by the data-processing center at OCAMA.

While this was a major modification of the original concept, the resultant system performed satisfactorily, partly because SAC, in the meantime, installed electronic data-processing equipment at each base for the maintenance of base inventory balances. This equipment automatically creates a punch card requisition and transmits it to the weapon system manager at OCAMA when the base balances fall below prescribed levels. Thus no manual keypunch effort is required in handling base re-supply, and one of the goals of the original concept is thereby attained. The only major deficiency is that the weapon system manager does not know the amount of inventory on hand at the base level world-wide at any time. Furthermore the stocks, once shipped to the base, are no longer considered a part of the weapon system manager's inventory. The original concept extended weapon system manager control down to the base level, so that shipments between bases could be directed by the weapon system manager to equalize stocks among bases.

Implementing the Weapon System Stock Control and Distribution System, Phase I for the B-52 and KC-135 aircraft involved 82-man-years, 10 of which were provided by RAND. The system was put into operation in December 1957 for the KC-135 and in January 1958 for the B-52.

The system was successful from the start. A review made in April 1959 concluded that the annual net additional costs of performing the same stock control and distribution functions by manual and/or punch card methods would amount to \$2,360,906. The "indirect benefits" of the system, listed in Appendix A, are highlighted by measurable reductions in AOCF (Aircraft Out of Commission Awaiting Parts) and ANFE (Aircraft Not Fully Equipped) rates, lower average depot backlog time, and increased productivity by using the computer to perform functions previously manual.

Phase I's success is partially attributable to the fact that there was no extreme pressure for implementing the system before it was ready. Target dates for implementation were set, but the existence of an operating, interim system reduced the pressure and permitted careful review and testing of the Phase I system.

INTERIM TAPE SYSTEM

The interim system utilized the IBM 650 computer with 6 tape units, and bridged the gap between the preceding punch card system and the full-scale Phase I system. It was a straight conversion to the computer of an older inventory control system which had been in use for some time. This older system, known as the "mark-sense offset" system, was entirely a punch card operation and consisted essentially of maintaining balances for stock items. No decisions (such as whether to ship an item or select a substitute) were made automatically, but rather were made by commodity managers, who used mark-sense punch cards to record their actions. Daily, (during the night shift) these cards were used to update balances, also maintained on punch cards, before the next day's operations began.

Although OCAMA believed that the Phase I system could be implemented directly from the punch card system, Headquarters AFLC, directed that the interim tape system be installed in case the Phase I was not successful. The interim system was therefore programmed during the early part of 1957, utilizing about one-half a man-year, and operated from July 1957 until December 1957, when the revised Phase I system began operating.

Even though the interim system may not have been necessary, the OCAMA personnel feel it had some positive results. Much of the data were corrected in the process of going from the card to the tape system, and transaction histories were put onto magnetic tape, thereby making them easier to use when the Phase I system was installed. In addition, the interim system provided a degree of security, since if the Phase I system had not proved successful, the interim tape system would have been a workable improvement over the punch card system it replaced.

PHASE II SYSTEM

Well before implementation of the Phase I system, a newer system concept was being considered. Toward the end of 1956, the B-52/XC-135 weapon systems manager stated that the stock control and distribution system would eventually have to be able to handle high priority requisitions on an on-line basis, with about one minute maximum processing time per requisition. This meant that while the Phase I system was still being developed, a new random access system had to be considered.

At the time (1956), no available equipment could handle both the required processing and the needed random access storage. RAND and OCAMA jointly developed the specifications for the required hardware which could make it possible to link the IBM 705 to a maximum of 64 disk files of 5 million characters each. The manufacturer agreed to produce the two required buffer or "disk control units" at a price of about \$305,000 each. The resultant equipment configuration consisted of two different arrangements. One arrangement, shown in Fig. 2(a), consisted of the IBM 705 II with random access disk units directly connected by means of the two custom-built disk control units (DCU's). This arrangement handled all routine transactions once a day, in much the same way that the Phase I daily processing did -- the main difference being that the main balance records were stored on disk units rather than magnetic tapes. The second equipment arrangement, shown in Fig. 2(b), consisted of the same disk units, but connected to an IBM 305 computer, with one random access disk memory. This arrangement is used for handling high priority requests as they are received. This equipment configuration supports the Phase II, or "disk," system, which operated from April 1960 to May 1964.

The system had the following characteristics:

The master record is maintained on disks and consists of essentially the same information as that maintained on tape and used for processing in the Main Balance run of the Phase I system. In addition, the disk record contains information referring to the disk locations of other parts in the family. This makes possible

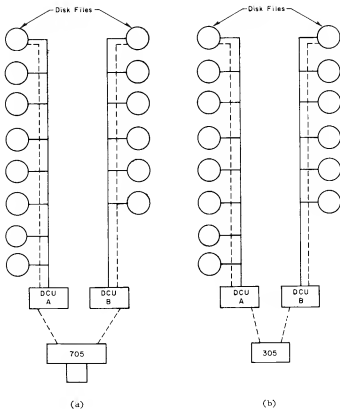


Fig. 2 -- The OCAMA Phase II System, November 1961; Simplified Equipment Configuration for (a) Daily Processing and (b) On-Line High Priority Processing

the location and retrieval of the records for all items in a family should they be needed. The master records are located on the disks by a randomizing routine, that uses the stock number, and they therefore do not follow each other sequentially by stock number as in the tape system. This presents a problem which will be explained later.

In the Phase II disk system there is no master record equivalent to the S&A master used in the Phase I tape system. Rather, each stock number of an item belonging to a family refers to the number of the next item in the family by disk address, until the entire family of records is obtained. The elimination of the S&A master record in the Phase II system had the advantage of removing the need to reconcile balances on two master records (Main Balance and S&A).

In the routine daily processing, transactions are sorted by stock number, edited, then matched against the master index tape in the classification run. The master index tape used in the Phase I classification run remains essentially unchanged except for the addition of the disk address of the stock number to each record. The main new action carried out in this run is the assignment of the disk address of the stock number to each transaction.

The transactions are then processed in the main balance run. The master record for each part is easily located by use of the disk address obtained in the classification run. For bachelor items, this one retrieval is all that is necessary. For filling requisitions for family items, all master records for the family are located in a chaining operation, where the record for the requested part is first retrieved; that record refers to the next record in the family, and so on. These records are temporarily stored on a magnetic drum until needed, at which time they are brought into the main core memory for processing. The Phase II system solves the problem of management by subfamily and substitution by subfamily and family, and at the same time, eliminates the need for the S&A master tape used in Phase I.

The Phase II system also has the advantage of being able to handle high priority requests by use of a small computer without waiting for the once-daily cycle. When the disk units are not being used with the IBM 705 in the daily processing, they are used by the IBM 305 with its one Random Access Memory (RAM) unit. This frees the 705 for use in other processing while the disk files are available for high priority requests for approximately 16 hours per day. The other 8 hours they are either used with the 705 for the daily processing or are turned over to the manufacturer for maintenance.

Transactions come from bases and storage sites to OCAMA either via punch card or via magnetic tape. All transactions other than high priority requests from the bases and receipts at the storage sites are accumulated and processed in the daily cycle. The receipts and high priority requests are processed within a few minutes of receipt on the 305 processor. Utilizing an index file, and any other records required from the same family, the 305 locates the master record, brings it/them into the 305 main memory, and executes the appropriate routines. The updated record/s is/are then stored in the RAM unit as a suspense. The main disk master record is unchanged because it is not possible to write a master record by using the 305. Any record which is read into the 305 and altered is maintained in suspense in the 305 RAM unit until the next daily processing cycle performed on the 705. The suspense portion of the RAM storage is always interrogated first in the processing cycle in order to determine whether the master record as stored in the main disk units has had any action since the last daily processing.

This on-line processing system is used for all requisitions having a priority of 1 through 8, and for all receipts. The receipt transactions were added to the on-line processing after the system became operational because more priority requisitions could be filled if receipt transactions were posted as they arrived at OCAMA instead of being held for the daily cycle. All actions taken during the on-line cycle are later posted to records in the main disk file by the 705 in the daily processing run.

In addition to these operational characteristics, the following statistics describe other features of the Phase II system.

Equipment complement:

- 1 IBM 705 II Processor, with 40,000 character core memory
- 18 Tape units
- 14 Disk files, plus two specially-built buffer disk control units
- 1 60,000 character magnetic drum
- 1 IBM 305 Processor, with 5 million character disk unit
- Monthly equipment rental cost: \$90,000
- Purchase price of the two special buffer units: \$610,000

Weapon systems controlled:

- B-52 Aircraft
- KC-135 Aircraft
- GAM 72
- GAM 77

Total number of master records (stock items) in the main balance file:

184,000; characters per record: 500 maximum

Total number master index records in the classification file tape:

184,000; characters per record: 95 maximum

Number of parts belonging to families: 29,000 (16 per cent of total)

- Average number of parts per family: 3
- Maximum number of parts per family: 50
- Average number of parts per subfamily: 1
- Maximum number of parts per subfamily: 32
- Maximum number of subfamilies per family: 25

Number of Air Force bases requisitioning from OCAMA: 61
(Each can have any number of the 4 weapon systems.)

All requisitions (except telephone requests) are received via the AUTODIN network.

Average number of transactions (all types) per day: 25,000

Average number of high priority (1 through 8) requisitions per month: 30,000

Number of man-years required to develop and implement Phase II: 17

This 705/Disk (Phase II) system proved to be quite suitable for handling the Air Force's requirement for immediate processing of high priority requisitions, handling them on the average in 20 seconds. During the Phase II's 49-month life from April 1960 to May 1964, no basic changes were made in the system concepts, although some redesign and reprogramming were associated with project MILSTRIP, described below. The equipment configuration was modified twice to take advantage of more powerful hardware: a) in November 1961, the original 24-disk units were replaced with 14 double-density disk units; b) in December 1963, the IBM 705 main processor was replaced by an IBM 7080.

Compared with the Phase I system, the Phase II system has certain advantages as well as disadvantages. The main advantage is its ability to handle high priority requisition on a 20-second basis, and this is the basic reason for the system's existence. Another advantage is the elimination of the S & A master tape and therefore the requirement for reconciling the balances on that tape and the Main Balance tape. This advantage has been partially offset, however, by the necessity of maintaining the current disk address for each stock number in each record on the master index tape used in the classification run.

The main disadvantage of the Phase II system concerned the arrangement of the master records on the disks. When management reports are prepared, usually in stock number sequence, it is necessary to "dump" all 14 disk files onto tape -- a process taking about four hours -- and then sort the tapes by stock number using the 705, (another lengthy process).

Significantly, the problem of producing reports in stock number sequence did not seem to be as important at the time of developing the disk system as it eventually became because it was originally expected that with an automatic system there would be few such complete reports. Most reporting was expected to be on a "management by exception" basis, requiring very little sorting into stock number sequence. The weapon system managers, however, continued to want complete reports by stock number, and this required more file dumping and tape sorting than was expected.

Another disadvantage of the disk system results from the possibility that a disk can lose some of its recorded data in transmission. As a precautionary measure, therefore, all disk files are dumped onto tape every 15 days so that the records can be reconstructed from the last such tape if necessary. (Such reconstruction has been necessary two or three times.) Since the disk files are dumped on a regular schedule, the times for taking physical inventories have been limited to dates coinciding with one of the dump cycles, causing some minor inconveniences.

The major differences in the Phase II (705/Disk) system and the original Phase I system as conceived by RAND are:

1. Supply management used for handling requisitions and substitutions were reduced from four in Phase I to three in Phase II. In addition, two of these three levels are not carried in the master record but are instead computed each time there is a part issue. The supply management levels in the Phase II system are:

a. Stock Control Level (SCL) -- This is carried in each master record and is the number of parts which is to be maintained in stock. Re-orders are made in a quantity to bring the balance to this level.

b. Re-order Level -- This is equal to 50 per cent of the SCL. Whenever an issue is made, this level is computed and compared with the resulting balance on hand to determine whether it is necessary to re-order. If so, an amount needed to bring the balance to the SCL is ordered.

c. Minimum Reserve Level (MRL) -- This is also computed when issues are made. For low value items, it is 1/12 of the SCL. For all others, it is 1/6 of the SCL. In filling requests, priorities 9 through 20 cannot be filled if the resultant balance on hand will be less than this MRL. Priorities 1 through 8 have no such restriction. In addition to these levels there is a Maximum Release Quantity (MRQ).

The MRQ is calculated as needed and is 1/5 of the SCL. It provides a screening applied to all requisitions; if a requisition exceeds MRQ it is referred for manager approval.

All of the levels used in the Phase II system are maintained for family items by subfamily, in accordance with the philosophy of managing interchangeable parts as one part. This involves no change from Phase I.

It was originally expected that elaborate means of calculating levels for each part would be employed, the result being unique quantities for each level and part. In this case, the levels would have had to be carried in the master record for each part. However, since all levels are a constant percentage of the SCL, it proved more efficient to calculate them as needed, saving storage space and eliminating constant updating of changing levels.

2. Substitution of parts was originally envisioned as being made on the basis of aircraft type, model, and series. A large programming effort was invested to implement this original concept. However, providing input transaction data concerning part substitutions by aircraft serial number proved to be impossible. Too often modifications were made to an aircraft in the field with no information about the modification being sent to the data center personnel responsible for S & A records. Therefore, the program was changed to make only those substitutions which are known to be applicable on all aircraft. The routine for substitution by aircraft serial number is still intact, but is by-passed ("no-opped") during the processing cycle.

The Phase II system proved so successful that few changes in concept were made in Phase III, which consisted primarily of employing more advanced data-processing techniques. Before describing Phase III, however, let us briefly review a partial reprogramming of Phase II which required substantial effort in terms of man hours. This reprogramming effort was known as project MILSTRIP.

PROJECT MILSTRIP

In July 1962, project MILSTRIP (Military Standard Requisitioning and Issue Procedure) was adopted by the Air Force and other services by order of the Department of Defense. MILSTRIP standardized all requisitioning and issue document formats used by the services. These format changes caused a reprogramming of all input/output aspects of the Phase II stock control and distribution system at OCAMA.

Reprogramming to handle the new formats under the MILSTRIP project was begun at OCAMA in January 1962 and lasted until the procedure went into operation the following July. That a total of

five man-years was expended on this reprogramming operation emphasizes the time-consuming efforts required to make modifications in complex data systems.

PHASE III SYSTEM

Phase III of OCAMA's stock control and distribution system began in May 1964, and now supports the B-52, C/KC-135, GAM-72 and GAM-77 weapons systems, and the B-47 and KC-97 accounts. It employs an IBM 7080 computer and returns to the concept of carrying the master record for each part on magnetic tape rather than on disks. However, an abbreviated master record is also maintained on disk files. This abbreviated record contains only the information required to handle high priority requisitions, on an on-line basis, still by use of the IBM 305 processor. Since the 305 cannot write information, the disk records are updated in the daily batch processing on the 7080. Every tape master record which is changed in the daily processing is copied onto a separate tape used for updating the disk files.

This change from the Phase II system has several advantages. First, the number of records which can be stored on disk (and are therefore available for high priority processing) is 2-1/2 times greater than previously, since the abbreviated disk record for each part contains 199 characters rather than the 500 employed in Phase II. The number of data fields in the disk record is reduced from 81 to 46.

This additional disk storage capability was not needed for the presently controlled weapon systems, so the number of disk units was decreased from 14 to 6. Together with accompanying reductions in processing time, this improvement effects annual savings estimated at \$695,076. Furthermore, the shorter disk record provides a capacity for expanding the scope of the system to 20 weapons (650,000 line items) from the present four.

The Phase III system, because it uses tape for the master file, also eliminates the need to dump the disk file semi-monthly. The tape orientation also decreases sorting requirements, since "bachelor" items, which account for 84 per cent of all parts, are sequenced by

stock number. The other 16 per cent of the parts are arranged by family number and are the only ones requiring sorting into stock number sequence.

Another advantage of Phase III is that the daily batch processing is shortened by about two hours, enabling the 305 to process high priority requisitions for two additional hours each day. In addition, the 305 processing speed has been reduced from an average of 20 seconds per transaction to 10 seconds per transaction, thereby providing a more responsive priority processing system.

This arrangement of records, wherein the master is on tape but an abbreviated portion of each record is on disk (for priority processing), could have been implemented in one of the earlier phases had it been known that families would be as small as they actually are. Instead of the expected number of at least 100 parts per family, the families average only three, with a maximum of 50. It is conceivable that all substitution relationships have not been identified, but experience over an eight-year period suggests that the original system was "over-designed" in that it was set up to handle much larger families than have actually been compiled. Had family size been known, the Phase I system would not have required a separate S & A master tape as well as the main balance master tape, and the Phase II system could have been similar to the Phase III system as it presently operates.

The Phase I system was over-designed in two other respects, mentioned earlier, but repeated briefly here. The system was designed to handle more precise interchangeability information than it has been possible to collect; for this reason, parts substitutions peculiar to a specific aircraft are not made. Second, the Phase I system envisioned more supply management levels than proved useful. Not only are fewer levels being used for managing each line item, but two of these (re-order and minimum reserve) are computed whenever an issue is made, rather than being carried as a data item in the master record.

In retrospect, it appears that these developments could not reasonably have been anticipated in the design of Phase I. They grew out of the operating use of the system, and are traceable more

to management considerations than to those concerning the data-processing system, per se.

The separate phases in the development of the system are compared schematically in Fig. 3.

PERSONNEL

In 1955, when the electronic inventory control system was beginning, OCAMA had practically no personnel experience in electronic data processing. OCAMA met the problem by transferring personnel from other jobs to new electronic data-processing positions. Most of them had some punch card experience; all were eventually trained in the use of large scale computers.

Considering the magnitude of the weapon system stock control and distribution job and the limited relevant experience of these personnel, the results of the operation are impressive. The personnel successfully programmed a new type of equipment to carry out a new concept of inventory management on new weapons systems just being phased into the Air Force.

At RAND's request, OCAMA stationed two men at RAND for one year so that the development of the Phase I concept would be soundly based on Air Force operating requirements. These two men also played an important role in relaying the details of the concept to the OCAMA personnel. In addition to the two OCAMA men, about five RAND personnel participated in developing the basic concepts for the original system. Nearly all computer programming was done by OCAMA personnel.

Until September 1960, all OCAMA personnel involved in the project performed both systems analysis/design and programming tasks. On that date, these tasks were separated, and personnel became either systems analysts or programmers. On large jobs, the system analysts and programmers work together from start to finish. On smaller jobs, the systems man does all the work through systems flow charts; the programmer then draws logical flow charts and performs the computer coding.

Both management and the personnel involved seem to prefer this mode of operation for two reasons. First, the systems analyst is more

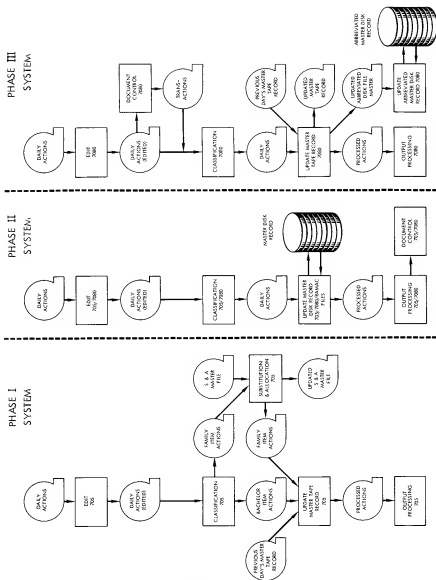


Fig. 3 -- Comparison of Phase I, II and III Systems

available for working directly with the customer (in this case the weapon system manager) in determining his needs and how they can best be satisfied. Second, the programmer is not hampered in his approach by being concerned with excessive systems details which do not concern the computer program he must write.

IV. SYSTEM IMPACT ON OTHER PROJECTS

Not only has the OCAMA system been a success in its own right; it has also had a definite influence in the conceptual development of at least two phases of another major Air Force system -- the Item Management (IM) Package. The IM system has objectives similar to those of a weapon system, but is concerned with controlling Air Force stocks by line item. The computer programs for the IM system were written at Headquarters AFLC, for use by all the air materiel areas concerned.

The IM system, prior to January 1964, was a tape system almost identical to the Phase I OCAMA system, partially because the OCAMA system was studied in detail and used as a starting point for developing the IM system. The IM system maintains an S & A master tape as well as the main posting master tape, and these are used in a manner similar to OCAMA's Phase I. Instead of "families" and "subfamilies," the IM system refers to "groups" and "subgroups." One minor difference in actual management is that in the IM system only the most preferred (usually the newest) item in a family is replenished, while in the weapon system often more than one part in a family is continually replenished.

The current IM package employs the IBM 7080, but does not have a high priority immediate response capability because no random access storage is provided. All of the 110,000 non-weapon system items for which OCAMA is the responsible air materiel area (AMA) are managed by the IM system, which entails a 2-1/2-hour computer processing cycle twice a day.

The IM system has experienced few problems other than some associated with centralized programming. The basic programs were written at Headquarters AFLC, and AMA's are not allowed to make changes other than "quick fixes," which must be reported to Headquarters AFLC. The AMA's are allowed to "supplement" the IM program if the basic program is left unchanged and the running time is authorized by Headquarters AFLC. Some difficulties in the early days were experienced with programs prepared centrally not being fully debugged before distribution to the AMA's.

The IM system is undergoing a revision known as the Priority Distribution System (PDS). This will incorporate random access storage for handling high priority requests in a manner similar to the OCAMA Phase II system. The major differences from the Phase II system are as follow:

First, the random access units will not be connected directly to the main processor (in the Phase II system the disks are connected to the 7080). Instead, when daily batch processing takes place, the random access files will be dumped onto magnetic tape for all processing on the main processor. After the batch processing, appropriate data from the tapes will be loaded back onto the random access units. This operation is feasible since it takes only six minutes to load one of the newer disk units, compared to one hour required by earlier models used in Phase II.

The second major difference is that high priority requisitions are posted to the master record, not just "suspense posted" as in the Phase II system. This is possible because the new system will have the ability to write on the disks without going through the main processor.

In addition to a clear impact on the IM system, OCAMA's concepts played a role in the initial development of the ICBM management system (ARLS). However, this influence dwindled, and the ARLS project subsequently took on a posture all its own.*

The Phase III system developed by OCAMA has also been used by other air materiel areas to support other weapon systems. In April 1963 OCAMA's Data Services Division of the Comptroller recommended to AFLC that a standard Automatic Data Processing (ADP) System be developed to support all Volume XX SSM and Speed Through Air Resupply (STAR) Weapon System Control Points (WSCP's). AFLC agreed with this recommendation and in July 1963 designated OCAMA as the pilot AMA for development of the standard systems and programs. This assignment was completed in April 1964, and the system was implemented as Phase

* A Memorandum describing ARLS (Automatic Resupply Logistics System) is in preparation as one of this series.

III at OCAMA in May. Mobile Air Materiel Area implemented the system in June to support the F-105, and Ogden Air Materiel Area installed it for joint Air Force/Navy support for the F-4 in July 1964. Implementation at other selected AMA's is scheduled for the latter part of this year.

V. CONCLUSION

What can be learned from the successful development of the OCAMA stock control and distribution system?

First, the system concept had a specific focus -- the stock control and distribution phase of inventory management. Although the original RAND concept included other functions (such as transportation scheduling, elaborate requirements and procurement computations, and maintenance scheduling), it was early decided (in 1956) that if the stock control and distribution phase were solved first, the other phases could be added later. It was agreed that stock control and distribution is the fundamental function of the inventory management process, and the necessary foundation for any subsequent phases.

In retrospect, this approach appears appropriate since automation of the other functions envisioned by RAND rested on the development of new and complex techniques that have still not been perfected. When they are available, it will be possible to integrate them with the stock control and distribution system with a minimum of effort and to phase them in without pressure since the basic function is under control.

The lesson appears to be that in the creation of a large scale system, eventually intended to embrace many functional areas, it may be wise to develop the fundamental part of it first -- rather than attempting to develop all functions concurrently. This approach does not preclude eventual development of the system as an integrated whole. Nor does it constrain the spectrum of intended accomplishments. The concept may be comprehensive, but implementation within the framework of this concept should be planned in discrete, sequential steps.

Second, each phase of the system was successfully operated before a succeeding phase was undertaken. If OCAMA had not first had the original mark-sense punch card inventory control system (and the follow-on interim IBM 650 tape system), it is almost certain that the pressures to get the Phase I system "on the air" would have been considerable. With these systems, which performed adequately if not

elegantly, the new stock control and distribution system was not forced into operation until it was fully ready. This implementation philosophy continued through all of the system's phases. Delays in implementing any phase would not have been disastrous, since a working system was in existence. This emphasizes the desirability of providing for phased development in which each phase in itself provides a system that satisfies basic operational requirements.

Third, each phase was used as an opportunity for collecting information about the system and the weapon manager's data needs and decision processes. Much of such information could (and, in most systems, can) be learned only by involvement with an operating system. This was especially true with OCAMA where the system concept, the data processing equipment employed, and the weapons system involved were all new. Each phase thus formed an improved conceptual and operational foundation for the succeeding phase.

The reasons for the changes from phase to phase can be divided into three classes: 1) increased information about the character of the data describing the line items under control; 2) changes in management philosophy; 3) availability of more advanced data-processing equipment.

In considering the first class, it must be remembered that the nature of many of the data was not learned until the Phase I system had been in operation for some time. Examples are the sizes of families and subfamilies and the availability of interchangeability data by aircraft type, model, and serial numbers. The original system was designed to handle much larger families and subfamilies and more interchangeability information than later experience showed to exist. However, most complex, advanced systems must be developed with incomplete information, and as long as such uncertainty exists, some over-design in the initial phase may be desirable, providing the implementation concept provides for adjustment in future phases.

The second class of reasons for phase changes concerns modifications in management philosophy. The most significant change of this type was the reduction in number of supply management levels used in line item management. Levels are now computed as a constant percentage

of the stock control level (making it unnecessary to carry them as part of the master file), whereas the original plan was to calculate them on an individual basis in a quite sophisticated manner. Again, the initial system was over-designed to allow for more information than turned out to be needed for efficient management. As more experience was gained in the management process for these new weapons, the data system was modified appropriately.

Another unanticipated management requirement was for many reports of line item balances in stock number sequence. Management by exception was expected to prevail much more than it has, with the result that more central-processor time than expected was used in Phase II for sorting master records into stock number sequence for reporting purposes. This is one of the reasons for moving from Phase II to Phase III, which prepares reports by stock number with much less main-processor sorting time than required in Phase II.

The third reason for moving to the advanced phases has been the availability of newer data-processing equipment. During the development of the Phase I system it was known that a random access capability would have been desirable, but there was no equipment available for such a large scale system at the time. The random access requirement was therefore omitted in Phase I. Arrangements were later made with a manufacturer to build the required equipment, and the random access feature was added in Phase II. The concept was to design the best system with available equipment, rather than waiting for the "ideal," ultimate equipment.

In retrospect this evolutionary process of developing systems in discrete phases appears to have worked remarkably well at OCAMA. It is unlikely that Phase III could have been implemented directly without the foundation of former phases. Likewise it would not have been practical to defer any system until one embracing all features of the original RAND concept could be implemented.

The successful experience of OCAMA thus argues strongly the case for developing new, complex data systems by adopting a concept having specific focus and providing implementation in discrete phases, each of which constitutes in itself an operating system.

Appendix

INDIRECT BENEFITS -- STOCK CONTROL AND DISTRIBUTION SYSTEM

PHASE I

SOURCE: Performance Evaluation of Data-Processing Program
at Oklahoma City Air Materiel Area, April 1959.
(Transcribed)

Reduction of AOCP/ANFE Rates

AOCP (Aircraft Out of Commission Awaiting Parts) rates for B-52 aircraft dropped from 1.9 per cent in 1956 to a .8 per cent in December 1958. ANFE (Aircraft Not Fully Equipped) rates for the corresponding period of time dropped from 15.9 per cent to 2.4 per cent. Although not completely attributable to EDP, it is apparent that EDP influenced this drop of rates.

Reduction of Backlog Time

Average depot backlog time is 5.5 days as reported in the S-144 report. The average backlog for the B-52 Weapon System for the 705 EDPM processing is 3.4 days. The average backlog for the KC-135 Weapon System for the 705 EDPs processing is 2.8 days. Reduction of backlog is attributable to the direct machine processing of 89 per cent of all actions for the B-52 and KC-135 aircrafts. Thus more responsive service to tactical organizations has reduced volume of requisitions and held to a minimum the AOCP and ANFE rates.

Automatic Requisitioning

When the asset picture is equal to or less than the reorder point, a weapon system storage site replenishment requisition is automatically prepared for the quantity necessary to reach the stock objective level. This eliminates manual computation and preparation of requisitions for materiel. In addition, it allows for constant surveillance of site levels of materiel by EDP.

Priority Transaction Processing

The present system provides for direct processing for all priorities 1-5 received 1200-2400 hours with the exception of AOCP, ANFE, and Hi-Valu. This represents 67 per cent of all priorities 1-5, received. All priorities 6-16 credits, debits, stock list changes, issues and turn-in from maintenance activities, adjustments and file maintenance actions are batched and processed directly by the 705 EDPM. Detail balance and master card information previously maintained by the Weapon System Support Manager has been eliminated. A balance listing is provided the WSSM for manual processing of priorities 1-5.

Volume Processing with Minimum Expenditure of Manpower

From a total of 40,000 stocked items with 1845 transactions per day to a total of 127,000 stocked items with over 15,000 transactions per day, no additional manpower has been obtained for the Logistic Support Manager (LSM) for processing of same. Approximately 1 June 1959, the GAMs (Guided Air Missiles) 72 and 77 will add 50,000 items to the Weapons System with 5,000 transactions daily. 1 July 1959, the B-50 will add 7,000 items to the weapons with 300 transactions daily. An aggregate total of the five weapons systems is 184,000 items with 20,300 daily transactions.

Site Listings of Stock List Changes

Previously, a complete listing of stock list changes was prepared for the weapon manager to forward to each storage site. Prior to forwarding listings to the sites, each site balance card had to be checked manually against the listing in stock number sequence. Those part numbers on the listing not matching the balance cards had to be lined off. Currently a refined product is prepared, furnishing only those stock list changes applicable to storage site assets, thus eliminating the manual comparison.

Selection of Shipping Site

Selection of the preferred site from which shipment can be made is determined mechanically and the material release order prepared for the selected site. If total shipment cannot be made from the preferred site, the next site will be checked for total shipment. When all sites have been checked and the total shipment has not been made, partial shipment will be made from different sites in order of the site preference. The preferred site is the closest geographical location to the requisitioning base. This assists in getting requested material to the base more rapidly and economically. Complete or partial shipments may not be made from the preferred site if inadequate stockage exists, but rather complete shipment will be made from a less preferred site to eliminate unnecessary packaging, handling, transportation costs, and paper work.

Substitution and Allocation of Material

Substitute and allocation operations provide interchangeable or substitute items to fulfill a demand when substitution is required because of inadequate balances or when the manager desires to purge the system of least desired stock of the item requested. Levels, balances, application, and order of substitution are interrogated to determine the item to ship. This also allows for the depletion of older stock from the warehouse, conservation of warehouse space, controls disposal action, and provides better support to the customer.

Stock List Changes

Stock list changes are automatically converted to the new identification number in the regular daily file maintenance routine. Requisitions for stock list changed items are automatically converted to the new number for supply action processing. Current and up-to-date stock list change data is maintained for all items. This allows for shipping actions without unnecessary manual research to up-date the stock number to the most current stock number.

Due-In Materiel

In addition to maintenance of balance file records now on magnetic tape and the processing of transactions pertaining thereto, provisions have been made for utilization of magnetic tape data from the contractor covering more current due-in assets. Due-in assets are considered during daily processing when back ordering and preparation of automatic requisitions for storage site replenishments.

Back Orders

In checking the system balance, if it is determined that a shipment cannot be made in whole or in part, a back order will be made when a sufficient due-in balance exists. If it is not possible to place it on back order, a shipping order on the prime depot will be issued. Back ordering of an item allows for future shipping action for today's requisitions for materiel.

Back Order and Supply Priority Updated

Back orders are up-dated with stock list change information. Also the priority is automatically up-dated by comparing the current date with date the materiel is due for delivery. Cancellations are processed against the back orders and quantity is converted when unit of issue changes. When priority changes or the item has been received, the back order is re-examined for possible shipment.

Standardize Transaction Edit

Each incoming transaction is checked for validity, accuracy and completeness. Errors and transactions that cannot be identified are flagged for corrective action.

Updating of Priority

A comparison of the due date on incoming requisitions with the current date is made and the supply priority is updated if appropriate. Updating of priorities allows for shipping action to be taken to fulfill requisitions from the base to meet materiel requirements at a specific time.

Warehouse Refusal

In processing a warehouse refusal the priorities and levels are disregarded. The warehouse refusal is treated as a normal requisition resulting in a back order or shipping order if the other sites cannot support shipment. A warehouse refusal will result in a flagged balance and no other shipping actions will be processed against the item at that site until corrective action has been made. Debit transactions will continue to be processed during the time a balance is flagged.

Status Information

When a materiel release order, back order, or shipping order is created during the processing, a corresponding status card is made, complete and ready to be transceived to the consignee. Status cards should materially reduce the number of follow-up requests presently experienced by the weapon managers. This in turn decreases requisitioning bases and Hq OCAMA workloads due to decrease in follow-up preparation and processing.

Exception Data

Exception listings provide the medium for bringing rejects to the attention of the weapon manager. There are 25 reasons for rejecting transactions. The majority of these reasons represent improbable situations but must be provided for in the system. The most common causes for rejects are requests for a quantity in excess of maximum quantity allowable as determined by the Weapon System Manager and requests for materiel not stocked at the storage site. Other causes include part-numbered items not matching balance records, and requisitions for insurance or Hi-Valu items, controlled by the manager and processed manually.

Hi-Value Intransit Control

A system for recording and reporting stock balance data on in-transit category I materiel, which allows for all Hi-Valu materiel to be accounted for at Stock Balance Reporting time. Approximately 2.6 per cent of all items stocked at storage site are Hi-Valu. Hi-Valu items are those items costing \$500 or more.

Requirements Data

Furnishes accumulated data for stock balance and requirements purposes. These data are considered in the 705 EDPM requirements computation for determining stock procurement or excesses.

Internal Sequence of Introduction Arrangement

Sequence of introduction is determined and assigned for input of transaction for File Maintenance actions, adjustments, debits, and credits (in accordance with priority) to be processed in this sequence. For example, this allows for recognition of receipts of materiel before shipping actions are applied.

Minimize Input Conversion

Previous systems have required external coding and rearrangement of source data prior to input. Under the present system 95 per cent of the coding and 100 per cent of the rearrangement is performed internally by EDP equipment. This eliminates all external edits and rearrangement of input card formats.

Replace Erroneous and Garbled Data

Missing information is inserted from the master magnetic tape record and erroneous data is corrected when possible. For example, if the procurement source code, the ERC (Expendability Repair Code) or unit of issue is erroneous, the transaction is not rejected, because master record information is utilized. This assists in the reduction of rejects in the system and unnecessary delay in supply action. Also the requirement for reprocessing and resubmission of the requisitions is held to a minimum.

Stock Number Cross Reference

A cross reference is maintained for up to as many as three stock list changes applied against any one item. This permits processing of obsolete stock numbers on requests received from requisitioning activities without research or unnecessary delay.

Follow-Up Actions

A suspense record is established on all replenishment requisitions and shipping orders. If supply action is not specified by the Prime Depot, a weekly follow-up is made automatically by the EDP system on Priority 1-5 requisitions, semi-monthly on Priority 6-15 and monthly on Priority 16.

Assign IAM Codes Automatically

Assignment of IAM and posting control codes is accomplished automatically on receipts from contractor and machine shipping actions. This affords a means of developing segments of data utilized in the Requirements Computation and a means of monetary control of the weapons support.

War Mobilization Expansion

More mobilization expansion is possible with no attendant problems of acquiring additional personnel for special support. For example, the normal daily transactions are 15,000; however, on occasion, the daily transactions have exceeded 30,000. Result of this increase was one additional hour of 705 EDFM time. Under a manual system this would have created a backlog of three days.